DIABASE AND GRANOPHYRE OF THE GOWGANDA LAKE DISTRICT, ONTARIO

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INTRODUCTION

The rich silver deposits of Nipissing and Temiskaming districts of Ontario are believed to be genetically connected with intrusive diabases. Chiefly on this account, these diabases have received considerable attention from many Canadian geologists.

During the summer of 1909 special opportunity for studying these rocks was afforded by the Ontario Bureau of Mines, to the writer, while working in the vicinity of Gowganda Lake.

The results of this study form the basis of this paper.

GENERAL GEOLOGIC RELATIONS

A brief résumé of the geologic history of the Gowganda district[1] will be given in order that general relationships may be well understood.

The oldest rocks consist of a complex of chloritic and hornblendic schists (altered basic volcanics), cut by quartz porphyries; together with a minor quantity of jasper-iron formation and its associated schists. This schist series (Keewatin) was subjected to intense folding and its schistose character induced before the intrusion of the great granite batholiths which in numerous places in the area are seen cutting the series. This complex (Archaean) suffered a long period of erosion before the deposition of the sedimentary series now lying upon it. The lower series is made up of conglomerates, quartzites, and slates of varying thickness. This in turn suffered erosion, but apparently little disturbance, before the deposition of the conglomerate-arkose-quartzite series lying upon it. These series have been called Lower and Middle Huronian respectively. Into

[1] See also forthcoming report and map by A. G. Burrows, Ontario Bureau of Mines, 1910.

all the foregoing series are intruded sills and dikes of diabase, the sill-like form being generally assumed in the sedimentaries. The succession here noted is essentially that found in all the Huronian areas of northern Ontario which have received careful study. The diabase is of remarkably uniform character in widely separated districts.

Throughout the Gowganda area, with few local exceptions, the sedimentaries with their sills have been little disturbed. They lie in monoclinal blocks with average dips of about 12 degrees to the east.

NORMAL SILL DIABASE

The normal diabase of the sills is, when unaltered, a dark-gray, medium-grained, holocrystalline rock, of which the chief constituents are plagioclase and pyroxene with a very little quartz, micropegmatite, biotite, apatite, and black iron ore.

The plagioclase, amounting to about 60 per cent of the total, occurs in stout laths with average length of about 0.5 mm., idiomorphic against pyroxene. Extinction angles place it as medium labradorite, $Ab_{35}An_{65}$. Sometimes zonal growth is shown and in favorable cases the outer zone could be determined as acid labradorite, $Ab_{45}An_{55}$. The plagioclase is generally somewhat altered, minute scales of white mica being the chief product of alteration. The pyroxene is in irregular grains between the feldspar laths. There appear to be two varieties. Normal augite with the usual high interference colors, high extinction angle, and frequent twinning is the more common. The average size of individuals is about 0.5 mm. In lesser amount occur grains of average diameter 2.0 mm. without twinning, showing nearly always parallel extinction, but in some sections as high as 10 degrees inclination. The maximum interference color is a pale yellow of the first order; the optical character is positive as in the augite; a faint pleochroism is shown. Bayley describes a mineral in his Pigeon Point rocks[1] which seems to be identical. The relation of this pyroxene to the feldspar is the same as that of the augite, but the large size of its grains suggests that it *began* to crystallize sooner. The pyroxene is probably enstatite. The appearance of slightly oblique extinction in rare cases is to be explained in its

[1] *Bull. 109*, U.S.G.S., 36, 45.

wide axial angle. The slide presents no difference whatever from the diabase of the Cobalt area. Biotite, black iron ores, and apatite are the accessory minerals. Small areas of micropegmatite of quartz and an indeterminate feldspar are always present.

GABBRO

In places the diabase has moderately coarse phases with augite in stout prisms showing one perfect cleavage face, the diallagic parting, which determines the fracturing of the rock. The cleavage face is nearly always bent, sometimes into a considerable arc. This bending is a constant character of the augite of the coarse phase from widely separated points. Under the microscope this phase shows a nearly simultaneous crystallization of augite and plagioclase, the feldspar in broad areas generally inclosing the augite.

The feldspar is an acid labradorite, $Ab_{45}An_{55}$, approximately that of the outer zones of the crystals of the normal diabase. Some zonal growth was shown in a few examples, the outer zones being slightly more acid.

The pyroxene is augite throughout, with cleavage parallel to 100 and a lamellar structure parallel to the base. Enstatite is absent. The augite has often gone over, partly, to uralite. Both augite and plagioclase are in stout prisms of about 3 mm. average length. There is no evidence of granulation of any of the constituents, so the bending of the augite must be attributed to disturbance during crystallization. A little iron ore occurs, and moderately coarse micropegmatite interstices in small amount. The feldspar of these could not be determined. Where micropegmatite is in contact with iron ore and augite, secondary biotite has sometimes been built. The rock is a gabbro, near augite diorite.

No definite relation of the gabbro to the sill boundaries could be made out. There is usually a gradual passage from diabase to gabbro, but in some cases small dikelike masses of the gabbro were found in diabase. The gabbro probably represents the more slowly crystallized, slightly more acid parts of the sills. This phase is well developed in the area west of Logan Lake. In places in this area the gabbro becomes very coarse, with pyroxenes up to three inches in

length, often showing alignment, indicating motion in the mass during crystallization.

TABLE I

SiO_2	50.12				
Al_2O_3	15.70				
Fe_2O_3	1.42	Norm.			
FeO	6.89	Or	6.12	F=54.82.	Sal.=56.24
MgO	9.50	Ab	22.01		
		An	26.69		
CaO	11.30	Nep	1.42	L= 1.42	Fem.=43.34
Na_2O	2.91	Di	23.73	P=23.73	
K_2O	1.07	Ol	16.22	O=16.22	
H_2O+	1.03	Mt	2.09	M	
		Il	1.06		
H_2O-	0.21	Pyr	0.24	A	
TiO_2	0.55	III, 5, 4, 3			
S	0.14	Auvergnose			
	100.84				

I. Normal Diabase, O'Brien Mine, Cobalt. N. L. Bowen, Analyst

DIKES

In the Davidson Lake sill, which will be described later at greater length, a well-defined dike of fine-grained diabase was found cutting the normal sill rock. Slender laths of plagioclase averaging 0.3 mm. in length are set in a matrix of augite. The plagioclase is very fresh and ranges from acid labradorite to acid bytownite. Augite fills the interspaces and is sometimes altered to a felt of needles of low birefringence with skeletons of iron ore, like the alteration products described by Pirsson in West Rock diabase.[1] Iron ore forms about 15 per cent of the rock. There is a little pyrite, but at least some of this has filtered in along tiny seams. No quartz could be found.

Dikes are exceedingly numerous in the Archaean, often up to 250 feet in width and of very uniform character. With the exception of the chilled margin the dikes are in most cases composed entirely of dark-gray, rather fine-grained, normal diabase. Sometimes, however, large phenocrysts of feldspar up to 2 inches in length, often with a flow arrangement parallel to the walls, stand out on the weathered

[1] Diller, *Educational Series of Rock Specimens*, 271–72.

surfaces. One especially fine example lies east of Davidson Lake where a dike about 200 feet wide, cutting the Archaean complex, shows phenocrysts from wall to wall. Only one dike, definitely determinable as such, was seen in the sedimentaries and this was near the basement Archaean. This was of the porphyritic type. The phenocrysts carefully determined in oriented sections are mainly a uniform andesine, $Ab_{55}An_{45}$. A narrow outer rim usually shows zonal growth with zones of labradorite, $Ab_{45}An_{55}$, and andesine alternating. In some cases the phenocrysts contain idiomorphic crystals of olivine near their outer edges.

The ground-mass consists of plagioclase, augite, olivine, apatite, and iron ores.

The plagioclase is mainly labradorite sometimes showing zonal growth, with acid andesine forming the outer zones. In a few cases the core is andesine with a zone of labradorite surrounding it and then again andesine as the outer layer.

The olivine is in small grains, usually very fresh. It is optically negative and therefore belongs to the iron-rich olivines. Most of it appears to have crystallized before the feldspar of the ground-mass. A brownish augite fills interspaces of the ground-mass between the feldspar laths in perfect ophitic structure. Apatite is unusually abundant, in very long needles, which penetrate all the constituents. No quartz or micropegmatite were found. Black iron ores are rather abundant.

GRANOPHYRE AND RELATED ROCKS

None of the dikes show evidence of differentiation as far as can be determined in the hand specimen. The sills, however, are not always entirely composed of the dark-gray diabase. In places we often see little pink spots, found to be areas of micropegmatite (quartz and albite). This material may increase in amount until it forms quite the whole of the rock, giving rise to "red rocks" or granophyres. Moreover pink aplitic veins are often numerous in the sills. To the development of these "red rocks" and their relations to the diabase and inclosing sediments attention will now be given.

DAVIDSON LAKE SILL

Close to the west shore of Davidson Lake is a sill about 50 feet thick cutting the arkoses of the Middle Huronian (Fig. 1).

Its western edge (the base) has a chilled margin against the sediments. The arkose has been bleached; otherwise there is no notable effect at the contact. As we approach the eastern edge (the top) we find "pink spots" appearing in the diabase. The actual contact could nowhere be found, but at one point the sill rock within a foot of the sediment was seen to consist entirely of a pink feldspathic

FIG. 1.—Ideal section at Davidson Lake. ark. = arkose; di. = diabase; gr. = Archaean granite.

variety. The microscope shows this rock to be made up of phenocrysts of acid plagioclase (albite to oligoclase-albite) in a groundmass of the same material with quartz and a small amount of augite and black iron oxide.

THE FOOT LAKE SILL

To the northwest of Foot Lake, diabase is found in contact with a narrow band of Lower Huronian slates (*A*, Fig. 2).

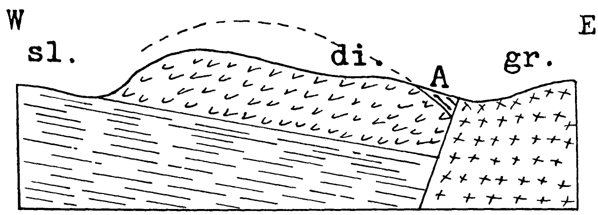

FIG. 2.—Ideal section of Foot Lake sill (laccolith). sl. = slate; di. = diabase; gr. = granite.

The slates near the contact normally greenish to pale reddish are changed in color to a deep purplish red. Under the microscope it is found that each lamina of sediment has been transformed to a mosaic of quartz and feldspar with a considerable proportion of chlorite and small grains of black and red iron ore. In the varying proportion of

chlorite and the varying "grain" of the mosaic the original lamination of the sediment is preserved. The feldspar is stained a deep red by tiny flakes of hematite. In a few individual grains albite twinning was discernible and the extinctions combined with the indices determined them as albite. Rarely small garnets are found.

It is typical adinole of diabase contacts believed to be produced by waters emanating from the diabase.

The intrusive becomes finer in grain as it approaches the sediment. For about three inches from the contact the diabase has a few "red spots" and these prove to be micrographic intergrowth of quartz and albite. The red color is seen to be due to little flakes of hematite in the feldspar. The plagioclase of the diabase proper has in large part gone over to sericite, and most of the augite to chlorite. Small pink garnets are an important constituent of this micropegmatite and sometimes amount to about 10 per cent of its bulk.

In places a zone of brecciated slate a few inches wide occurs along the contact. The "diabase" filling the spaces between fragments of slate is very rich in this pink micropegmatite (quartz and albite); is indeed sometimes composed almost entirely of it. Obviously the altered sediment has been influential in the production of this granophyric material (see Fig. 5).

About 100 yards south of the point just described, and on the same contact, the diabase has again these "red spots" near its contact and it passes rather abruptly into a reddish feldspathic rock about 5 feet thick. This is found under the microscope to consist of large phenocrystic individuals of albite in a ground-mass of quartz, albite, and chlorite. The quartz amounts to about 15 per cent and the chlorite to about 30 per cent, black iron ore about 5 per cent. A very few small garnets are scattered throughout the rock. The albite has again the tiny flakes of hematite, whence the red color. Small areas of very fine micropegmatite are found, showing the beginning of a granophyre structure. The rock has obviously the composition of adinole and passes quite gradually into the reddish-purple adinole which retains the structure of the original sediment. It is merely the more perfectly recrystallized adinole, closer to the intrusive. The granophyric material of special development in the diabase close to its contact has been introduced from the adinole at the time of its forma-

tion by some sort of "transfusion."[1] It has the same composition (albite and quartz, with some chlorite and garnets) as the adinole. In the diabase near this contact aplitic veins, consisting essentially of albite and quartz, are especially numerous.

LILY LAKE SILL

The diabase to the southwest of Lily Lake has often a high proportion of "red spots." On the north boundary of H.S. 646,[2] (*A*, Fig. 3) is found a variety which in the hand specimen would be termed a syenite. It is, in fact, composed almost entirely of the granophyric material which forms the "red spots." Under the microscope it shows phenocrysts of albite in a graphic intergrowth of quartz and feldspar, with a tendency to radial arrangement about the phenocrysts. The feldspar of the graphic growth is often in con-

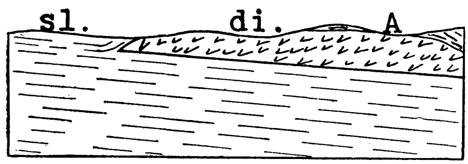

FIG. 3.—Ideal section at Lily Lake. sl. = slate; di. = diabase

tinuous orientation with the phenocrysts. Sometimes the albite twinning lamellae pass from the phenocrysts into the feldspar of the micropegmatite without interruption. A very small proportion of the feldspar of the graphic material is a microperthite. Chlorite, apatite, iron ore, and calcite are present in small amount. The rock is a typical granophyre.

There is a small patch of thinly laminated graywacke slate within thirty feet of the outcrop of this granophyre. It evidently overlies the granophyre, but the two could not be found in contact. Some of the slate is altered by the intrusive into a rock with alternating dark greenish chloritic and reddish feldspathic laminae. Other parts of the slate are less altered and some apparently unaltered. Some chemical determinations made in samples of the altered slate will be given later.

[1] A. Harker, *Natural History of the Igneous Rocks* (1909), 304.

[2] See map by A. G. Burrows, Ontario Bureau of Mines, 1910.

THE LOST LAKE SILL

The best exposure of granophyre found lies along the west shore of Lost Lake (Fig. 4). In the hand specimen it would be termed a hornblende syenite. It lies at the top of a diabase sill which diamond drilling has shown to have a thickness of more than 500 feet, probably much more. Here a vertical thickness of about 30 feet of granophyre is exposed on the hillside overlooking the lake. Capping the hill is a thin veneer of nearly flat-lying sediments. It is difficult to draw an exact line of contact. Between what is unquestionably altered sediment, and granophyre is a layer about 1 foot thick of a purely feldspathic rock, red in color, and very similar to the granophyre. The microscope shows only feldspar (albite), with a little calcite and blotches of chlorite. The altered sediment close to this feldspathic

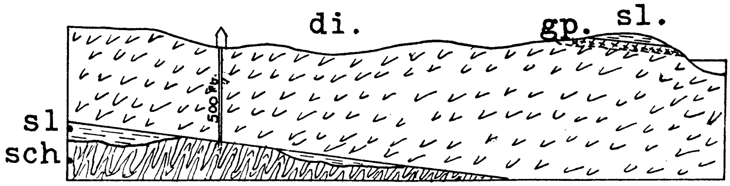

FIG. 4.—Ideal section at Lost Lake. sch. = Keewatin greenstone; sl. = slate; di. = diabase; gp. = granophyre.

layer has the granular appearance of a fine-grained indurated red arkose and under the microscope shows a mosaic of quartz and feldspar, some of which is determinable as albite. This gradually assumes a deep purplish-red color and in places passes into apparently unaltered slates. The whole change takes place within a distance of about twenty feet.

Going northward from the exposure just described there is a rather quick passage from granophyre, through diabase rich in granophyric material, to normal diabase, which is itself found in contact with little-altered slates. The granophyre is, then, not everywhere present at the upper contact of this sill, but for some reason is localized.

The granophyre itself is very similar to the Lily Lake rock. Albite phenocrysts are a little less abundant. A small part of the feldspar of the micropegmatite is microcline with, as before, some microperthite. The chlorite occurs in long blades probably secondary after hornblende. Calcite, apatite, and iron ores are again present.

TABLE II

	I	II	III	IV	V
SiO_2	62.54°	52.54	48.41	50.12	78.28
Al_2O_3	14.79	15.14	19.29	15.70	12.00
Fe_2O_3	...	0.85	1.33	1.42	....
FeO	8.49	10.73	8.27	6.89	1.19
MgO	2.08	5.22	4.70	9.50	0.37
CaO	1.49	6.92	4.93	11.30	0.29
Na_2O	6.27	5.46	5.92	2.91	6.89
K_2O	1.12	1.43	0.41	1.07	trace
H_2O	3.51	1.76	3.99	1.24	0.61
CO_2		....	2.41	....	....
TiO_2	....	1.00	0.88	0.55	0.34
	100.29	101.05	100.54	....	99.97

I. Lost Lake granophyre. Marked °, determined by N. L. Bowen, others by N. L. Turner.

II. Granophyric diabase, Pense Township. Analyst, N. L. Bowen.

III. Granophyric diabase, Bartlett property, Gowganda. Analyst, N. L. Bowen.

IV. Normal diabase, O'Brien mine, Cobalt. Analyst, N. L. Bowen.

V. Aplite vein in diabase, James Township. Analyst, N. L. Bowen.

TABLE III

	I	II	III	IV	V
SiO_2	....	62.54	60.70	75.43	79.43
Na_2O	5.12	6.27	9.33	5.72	4.73
K_2O	0.95	1.12	0.43	0.21	0.32

I. Lily Lake granophyre. Analyst, N. L. Bowen.

II. Lost Lake granophyre. Analyst, N. L. Bowen.

III. Albite rich layer at contact, Lost Lake. Analyst, N. L. Turner.

IV. Altered sediment near contact, Lost Lake. Analyst, N. L. Bowen.

V. Altered sediment near contact, Lost Lake. Analyst, N. L. Turner.

ORIGIN OF GRANOPHYRE

Summing up the evidence of the upper contacts of the sills, just described, we have at the Foot Lake sill, in one place, the special development of granophyric material in the diabase quite close to its contact with altered slate or adinole, the granophyre interstices having practically the same composition as the adinole and evidently derived from the latter by some process of transfusion. A little farther south where the action has been more intense we have a wider zone of adinole developed. Part of the adinole close to the diabase

has been to some extent recrystallized, giving the beginning of granophyric structure. The writer believes that in the case of the Lily Lake and Lost Lake sills the evidence points to a still more complete recrystallization of *part* of the adinole with the production of typical granophyre. In other words, some of the adinole was essentially in a state of aqueous fusion and crystallized as granophyre. The melt thus formed was, to a certain extent, free to diffuse into the diabase magma and gave rise to the abundant granophyric interstices near the granophyre.

If we inquire into the conditions of the formation of adinole from slates, we will find that wholesale introduction of albite, as such, is not necessary. Some magnesia, iron, and alumina are lost by the sediment. Silica has probably not been introduced, for the loss of the above-mentioned constituents suffices to increase the silica to the percentage in adinole. Finally potash, too, is lost and at the same time is replaced by soda.[1] Carbonate waters bearing a little soda could accomplish the work necessary. That such waters exist in basaltic magmas and have important effects during the late stages of crystallization is the conclusion of Bailey and Grabham in a late article.[2] If the conclusions of the present writer are correct, such waters, emanating from the diabase, have produced the adinole and the albite-rich granophyre here described. The waters supplied most of the soda and the sediment supplied alumina and silica. Calcite is an almost universal constituent of the aplite veins associated with the granophyres. It has in some cases apparently crystallized together with the aplite minerals.[3] This certainly points to the presence of carbonate waters.

It has been pointed out that magnesia, iron, alumina, and potash are the chief constituents carried away in the production of adinole. Presumably the waters carrying these would lose their solvent power at no great distance, due to fall in temperature, and they would be deposited. The small patch of altered slate at a little distance from the Lily Lake granophyre (see p. 665) may have been thus affected. The microscope shows that the most altered parts are rich in chlorite

[1] E. Kayser, *Zeit. der Deutsch. geol. Gesell.*, XXII (1870), 103 ff.

[2] *Geol. Mag.*, VI (1909), 256.

[3] A. E. Barlow, *Jour. Can. Min. Inst.*, XI (1908), 272.

(magnesia, iron, alumina, silicate) and analysis shows that the most altered parts are also richer in potash.

	Much Altered	Less Altered	Apparently Unaltered
SiO_2.............	54.77	58.48	61.54
CaO.............	0.65	1.08	0.84
Na_2O............	4.85	4.81	4.73
K_2O.............	3.50	3.11	2.64

There is of course no check on original variation in the composition of the sediment, but the results accord so well with what would be expected, if the granophyre was formed as here imagined, that they are to be regarded as, in some degree, corroborative.

The partial analyses, Nos. IV and V, Table III, of the altered sediment (adinole) near the Lost Lake granophyre, together with its microscopic examination, show it to be an albite-quartz rock approximating the granophyre in composition. The nearly pure albite layer, No. III, Table III, between granophyre (recrystallized adinole) and adinole probably separated from the fluid granophyre. Albite is certainly in excess in the granophyre (note phenocrysts) and its separation toward the adinole would be especially favored by the composition of the latter.

That the granophyre "solution," formed as here imagined, was foreign to the diabase magma is indicated by the intense alteration of the constituents of the diabase near the granophyric interstices.[1]

The aplitic veins[2] (quartz and albite, often with calcite) which cut both granophyre and diabase were formed from the more aqueous residuum of the granophyre. They are especially numerous near a mass of granophyre. The extreme purity of their albite (note analysis No. V, Table II) points to their aqueous origin, as does also their calcite content. This aqueous residuum probably deposited also the valuable metallic content of the aplite veins and of the associated calcite veins. The association of gold with the similar soda-rich rocks of Alaska, California, and Ireland is worthy of note (see p. 671, below).

[1] See A. E. Barlow, *Jour. Can. Min. Inst.*, XI (1908), 271.

[2] N. L. Bowen, *Jour. Can. Min. Inst.*, XII (1909), 95–106.

The extent to which the comparatively simple relations, exhibited at the contacts described, would be obscured by reintrusion of the mixed magma to a higher level may well be imagined.

DISCUSSION

As opposed to the explanation of the origin of the granophyre here advanced, the explanation which would probably first suggest itself is that diabase and granophyre are normal differentiates from a common magma, influenced by gravity. This assumption would neglect the evidence of the Foot Lake contact. Here highly granophyric diabase has developed between the slate fragments of the contact breccia.

Some of the dikes which feed the sills have a width greater than 200 feet. Assuming a normal differentiation in the sills, it seems likely that it would take place in dikes so wide, giving enrichment in granophyric material toward the central portions. Evidence of this could nowhere be found.

The Foot Lake sill has a thickness of only 50 feet, yet it has the acid rock developed at its upper contact.

The theory here advanced also accounts logically for the passage of granophyre into adinole of approximately its own composition.

It has been stated that the diabase in all parts of the sills shows micropegmatite interstices. Possibly much of this material may have an origin entirely different from that of the red interstices close to the granophyre. It should, however, be remembered that the dikes are sometimes without micropegmatite.

The separation, which is here postulated, of soda-bearing carbonate waters from the magma is of course a sort of differentiation, but is not in itself sufficient to produce granophyre but only to contribute to its formation by inducing alteration of the *slaty* sediments.[1] A necessary conclusion seems to be that granophyre would not have been formed had the country rock of these intrusions been pure limestone or pure quartzite just as adinole is not produced in such cases.[2]

This conclusion suggests a test of the hypothesis here advanced in

[1] The importance of contact metamorphism in the genesis of igneous rock types has long been advocated by the French school of petrologists.—A. Michel-Levy, *Bull. Soc. Geol. Fr.*, 24 (1896), 123 ff.; also 25 (1897), 367.

[2] W. Hutchings, *Geol. Mag.*, II (1895), 122–63.

examining the association of albite-rich igneous rocks described in the literature.

In California[1] the soda-syenite famous for its association with the Mother Lode gold deposits occurs along the contact of basic igneous rocks with Mariposa slates. This syenite is in places an almost pure albite rock; at others it contains some quartz and muscovite.

In Alaska the Treadwell soda syenite[2] of the Treadwell mine cuts slate and is followed by gabbro.

In Ireland, at Croghan Kinshela, albite granite here associated with normal potash granite cuts Silurian slates.[3]

In the Isle of Man albite-rich dikes associated with diabase cut Silurian slates.[4]

The albite-rich keratophyres of Westphalia cut slates.[5]

Quartz keratophyres in Australia are associated with diorites and cut slates.[6]

A notable point concerning all of these is their small quantitative importance.

If we extend our search to rocks rich in plagioclase near albite, we find the same general association.

In the Marysville district of Montana a rock made up of quartz 40 per cent, oligoclase-albite 40 per cent, magnetite 10 per cent, muscovite 10 per cent, has been produced at the contact between gabbro and altered argillaceous sediment by a process of "hydrothermal alteration along the contact plane."[7]

Plumasite, an oligoclase-corundum rock, occurs in California as a dike cutting peridotites which in turn cut clay slates.[8] It has been considered genetically related to the albite syenites. The excess of alumina (corundum) in the plumasite is suggestive in relation to its genesis by interaction of the basic magma and clay slates.

[1] H. W. Turner and F. L. Ransome, *Folios 41, 43,* and *63,* U.S.G.S.

[2] G. F. Becker, *18th Ann. Rept.*, U.S.G.S., Part III (1896), 39 and 65; C. W. Wright, *Bull. 287,* U.S.G.S., 95.

[3] S. Haughton, *Q.J.G.S.* (1856), 268; W. J. Sollas, *Tr. R. Ir. Ac.*, XXIX (1891), 427.

[4] B. Hobson, *Q.J.G.S.* (1891), 432.

[5] O. Mugge, *L.J.* (1893), B.B. VIII, 535.

[6] A. Howitt, *Geol. Survey Victoria*, IV (1877), 75–117.

[7] Barrel, *P.P. 57,* U.S.G.S., 48.

[8] A. C. Lawson, *Bull. Univ. of Cal.*, III, No. 8, p. 219.

At very many places in the British Isles granophyres associated with gabbro occur. Rosenbusch notes this general association.[1] At many of these places the granophyre is especially rich in plagioclase near albite and together with the gabbro is intruded into *slaty* sediments. The Carrock Fell[2] granophyre and the Buttermere and Ennerdale granophyre are perhaps the best-described examples. In the latter case it has been demonstrated that the associated Mecklin Wood dolerite has reacted with the sedimentaries.[3]

Near St. David's Head, Wales, *gabbroidal* sills cut Arenig *shales*. An oligoclase-rich rock has been produced near the contact by interaction with the sediment.[4] Granophyric interstices have also been produced near the sediment even where the contact-chilling effect is noticeable. It seems impossible to deny the influence of the sediment in the production of these granophyric interstices.

It would, of course, be quite unsafe to assume that the hydrothermal action here postulated was the dominant control in the development of the British granophyres mentioned. Some granophyres (micropegmatites) are believed by certain authors to have been produced by direct assimilation of sediments.[5] The result has been in these cases essentially a normal potash-rich granite. As pointed out before, assimilation of sediment has been noted in the case of some of the British rocks described, and this introduces new complications. It is rather their general tendency to richness in soda which indicates that hydrothermal action on the sediments may have had a part in their formation.

If albite-rich rocks were normal differentiates from a certain class of gabbroidal magma, they ought to be found in any association. The kind of "country rock" should make no difference. A search of the literature, summarized in the foregoing, seems to indicate that the kind of "country rock" does make a difference. It may be that argillaceous sediments are especially susceptible to the sodic waters;

[1] *Mik. Phys.*, II, 413.

[2] A. Harker, *Q.J.G.S.* (1895), 125; *ibid.* (1896), 320.

[3] R. H. Rastall, *Q.J.G.S.* (1906), 268.

[4] J. V. Elsden, *Q.J.G.S.* (1908), 275–76.

[5] W. S. Bayley, *Bull. 109*, U.S.G.S.; R. A. Daly, "Secondary Origin of Certain Granites," *A. J. Sc.* (4); A. P. Coleman, "The Sudbury Laccolithic Sheet," *J.G.*, XV, 773.

and this seems likely. Perhaps, also, water originally contained in the sediment and, in this class, in large amount, takes an important part in the transfer of material.

SUMMARY

1. The diabase of the Gowganda area occurs as sills and dikes cutting the older formations.

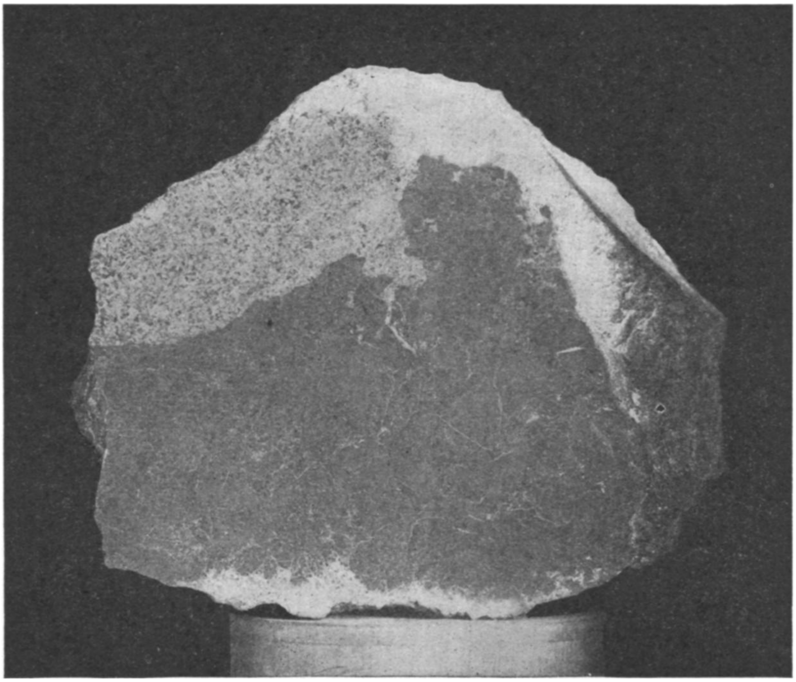

FIG. 5.—Photograph of polished specimen (natural size), showing light-colored granophyre-rich "diabase" against dark-colored, brecciated slate (Foot Lake).

2. The dike rocks are commonly porphyritic and olivine-bearing and never show distinct evidence of differentiation.

3. The sill rocks are never porphyritic; olivine is represented by the more silicic enstatite; granophyric interstices visible in the hand specimen as "red spots" sometimes occur.

4. A typical granophyre sometimes occurs at the upper contact.

5. The granophyre, like the granophyric interstices, is albite

rich and is transitional into albite-rich adinole, a product of contact metamorphism of slates.

6. The writer believes that the granophyre was, with the adinole, formed by hydrothermal action at the contact; it is an adinole which has crystallized from a state of aqueous fusion and hence with all the textures of an igneous rock.

7. The literature of albite-rich igneous rocks shows their general association with gabbros, intrusive into argillites, and leads the writer to believe that a somewhat similar action may be of rather common occurrence.

In conclusion the writer desires to thank the Ontario Bureau of Mines for those chemical determinations of this paper which were made by Mr. N. L. Turner, provincial assayer.